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MULTISTAGE RISKS PRIORITIZATION AND ALLOCATION TO VARIOUS EXECUTION MODES OF PUBLIC-PRIVATE PARTNERSHIP (PPP) INFRASTRUCTURE PROJECTS BY USING AHP

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Abstract
PPP involves long-term contractual engagements between private and public partners. The success of PPP infrastructure projects relies on comprehensive risk assessment, prioritization and equitable allocation. Limited literature is available on multistage risk prioritization and allocation in their relevant PPP execution modes. This research aims to fill the gap using qualitative and quantitative analyses for multi-stage risk ranking, prioritization and equitable allocation in respective execution modes of PPP infrastructure projects. The study assists in addressing uncertainties and enhancing the decision-making capabilities including effective multistage risk management before selecting suitable PPP execution modes. Categorized multistage risks have been identified for various PPP execution modes through an extensive literature review. Questionnaires and interviews were conducted for data collection and subsequent analyses using the Analytic Hierarchy Process (AHP) and NVivo to develop pairwise risk comparisons and hierarchy charts, respectively. The NVivo results highlight that risk preference varies in different execution modes and also gives overall preferred risks ranking like R8, R42, R50, R43, R37 & R22 etc. from the public perspective. However, AHP results give multistage prioritized risks ranking like R31, R27, R29, R4, R30, R33 & R2 etc. from a general stakeholders' perspective. Multistage risk categorization, prioritization and allocation in the respective PPP execution modes is a novel approach. The availability of limited PPP experts related to various execution modes was managed by categorizing PPP execution modes. Looking ahead, future researchers can explore and identify the extent of risk sharing among the various stakeholders to figure out this research gap.

1. INTRODUCTION

In a developing country, the government prefers PPP projects for the development and growth of the country because in PPP, the private partner sponsors maximum investment. Due to better investment, long contractual periods and complicated technology PPP project execution involves high risks (Akhtar et al., 2023). Each risk may be a source of another risk that may increase the severity of other risks during project execution and affect the project objectives (Mishra & Shah, 2023). Risk prioritization and proper allocation are crucial for PPP projects. Poorly assigned or allocated risks can potentially disrupt the project's advancement while it's being carried out. Since these projects require significant investments and have extended timelines, it's crucial to carefully assess project risks for proper allocation (Ke et al., 2013a). This analysis helps mitigate the impact of risks on project execution and successful completion (Nayak et al., 2022). It is crucial to consider various risk interdependencies for their proper prioritization based on the severity of each risk in the project. The successful execution and completion of PPP projects depends on the proper allocation of resources and the various risk identification, prioritization, and allocation processes that are involved in the project.(Akhtar et al., 2023)

There are three possibilities for risk transfer. The first is to transfer the risk entirely on the public sector, which is not possible because in most cases the public sector has less control over the project based on the execution modality of the PPP infrastructure projects. Due to that, the public sector hesitates to take responsibility for its own risk (Akbari et al., 2020). However, some risks could be better managed by the government if they are properly allocated (Akhtar et al., 2023). The second possibility is to transfer the complete risk onto the private sector which is happening in most of the cases because the private sector is financing, operating and executing the project, risk is transferred to the private partners, while the government has less control over the project in this situation. The third possibility in risk transferring is to share the risk in a weightage to both public and private sectors (Albalate et al., 2019). In the partnership agreement, the authority lists out common project risks and how they will be handled (Islamic Azad University et al., 2020).

If a risk isn't mentioned in this list, the government won't be responsible for any complaints and claims from the private party about that risk. It is crucial for PPP parties to identify and prioritize risk to assess significant risk (Sastoque et al., 2016). PPP initiatives are frequently complicated and fraught with major risks that might result in project failure or cost overruns. Incorrectly deciding which risks should be addressed first has led to strained relationships between the parties involved in contracts, resulting in higher project costs, delays, and poor quality (Mohsin et al., 2022). To prevent this, both the public and private sectors must fairly distribute risks to make informed choices (Song et al., 2022). It's important to recognize and rank risks tied to various types of PPP project execution modes. This ensures resources are used effectively and smart decisions are made to decrease risks' impact on project results (He et al., 2022).

Prioritizing risks benefits partners (public and private) by minimizing the chances and consequences of negative events while enhancing positive outcomes in project decisions (Shuliuk, 2021). While previous research has tackled optimal risk prioritization for construction projects, many studies have limitations. They lack a comprehensive approach to risk ranking, fail to connect risk ranking criteria with obstacles to project goals and neglect practical constraints of the allocation method, like the private sector's restricted ability to handle project risks (Vaslavskiy, 2021).

(Almarri & Boussabaine, 2020), described that PPP projects are complex because multiple risk factors interact with one another, potentially posing new risks and driving up costs in the end. They pointed out that the private sector is typically responsible for the majority of risk factors. It is believed that because a large amount of risk is shifted to the private sector in PPP projects, the public sector can obtain a higher value for money from these projects (Ameyaw et al., 2015a). Additionally, the funding agencies and the private sector can evaluate risk consequences and costs prior to the bidding process with the help of the suggested generic framework. This will allow them to optimize their bids and put in place mitigating strategies (Carbonara et al., 2014) (Liu et al., 2016).

This paper includes the **Section 2**, literature review highlighting the relevant literature available in the PPP infrastructure project including the available theories related to the study followed by **Section 3,** methodology which covers the detailed research design including data collection, detail of representative sample of PPP experts and comprehensive methodology adopted for AHP and NVivo. **Section 4**, data analysis and results includes detailed calculation by applying AHP analysis and NVivo software analysis for the ranking / preference through the development of pairwise comparisons and hierarchy charts of the identified risks. Pairwise comparison and hierarchy charts were discussed in detail stagewise for each phase of the project and on the basis of the calculations, the results were discussed in detail including the linking of the results of the study with the previous literature. Finally, the key prioritized / preferred risks stagewise and overall ranking were discussed in the conclusion Section 5. A comprehensive risk allocation and prioritization of risk matrix was also developed based on the data gathered from the respondents / PPP experts in Appendix A.

The NVivo analysis results show that the R8:Microeconomic variables, R42:Corruption, R50:Project transfer risks, R43:Political instability, R37:Operations and Maintenance risks, R22:Tenant risks, R40:The uncertainty in rent prices, R14:Ownership of assets, R54:Assets obsolesce, R7:Poor cost estimation, R1:Improper design and technical study, R9:Availability of finance, R23:Lack of flexibility in contracts, R31:Scop Creep, R38:Demand and revenue shortfall, R15:Change in law, R11:Revenue shortfall and R20:Legally week partnership or strategic alliance etc.. are key risks for the execution of PPP projects from the public sector perspective. However, the ranking of these risks varies in various execution modes of PPP infrastructure projects as shown in Appendix A.

Moreover, the link between risk ranking vis-a-vis PPP execution modes hasn't been clearly defined in previous research. The objectives of the study are to prioritize the following identified fifty-five (55) multistage risks and their allocation in various execution modes of PPP infrastructure projects.

R1: Improper design and technical study
R2: Land acquisition and compensation
R3: Required initial approvals for a feasibility study
R4: Improper preliminary survey
R5: Inherent risks to conceiving PPP projects
R6: Multilateral agencies and stakeholders' involvement
R7: Poor cost estimation
R8: Macroeconomic variables
R9: Availability of finance
R10: Fulfilment of commitments with financial institutes
R11: Revenue shortfall
R12: Financial rate of returns on investment
R13: Financial insolvency of the host government
R14: Ownership of assets
R15: Change in Law
R16: Insolvency of the public or private sector
R17: Third-party reliability
R18: Institutional nature arrangement
R19: Encumbrances of land
R20: Legally weak partnership or strategic alliance
R21: Inefficient procurement process
R22: Tenant risks
R23: Lack of flexibility in contracts
R24: Market demand for assets
R25: Legal aspects of the property
R26: Expropriation
R27: Poor quality
R28: Unproven engineering techniques
R29: Unforeseen construction cost overrun
R30: Availability of land for use
R31: Scope creep
R32: Inadequate health and safety measures
R33: Delay in a construction period
R34: Availability of labor and material
R35: Protection of geological and historical objects
R36: Shifting of utilities
R37: Operation and maintenance
R38: Demand and revenue shortfall
R39: Frequency of maintenance
R40: The uncertainty in rent prices
R41: Toll slippages
R42: Corruption
R43: Political instability
R44: Environmental permits
R45: Ground and weather conditions
R46: Lack of R&D in the PPP regime
R47: Natural disasters or force majeure events
R48: Transfer of technology
R49: Inherent risks
R50: Project transfer risks
R51: Residual value risks
R52: Depreciation of asset
R53: Completion of project

R54: Asset obsolescence R55: Asset maintenance

2. Literature Survey

There is no single PPP execution mode that fits all situations and carries same kind of risks. Researchers have identified different PPP models based on how much the private sector is involved in funding and managing the project (Akhtar et al., 2023). Each sector chooses a specific PPP execution mode based on its own characteristics, like unique needs and available choices. The model also depends on the sectors involved, such as education, health, and transportation, as well as the size and nature of the project. Figure 1 shows PPP models (Liu et al., 2016).

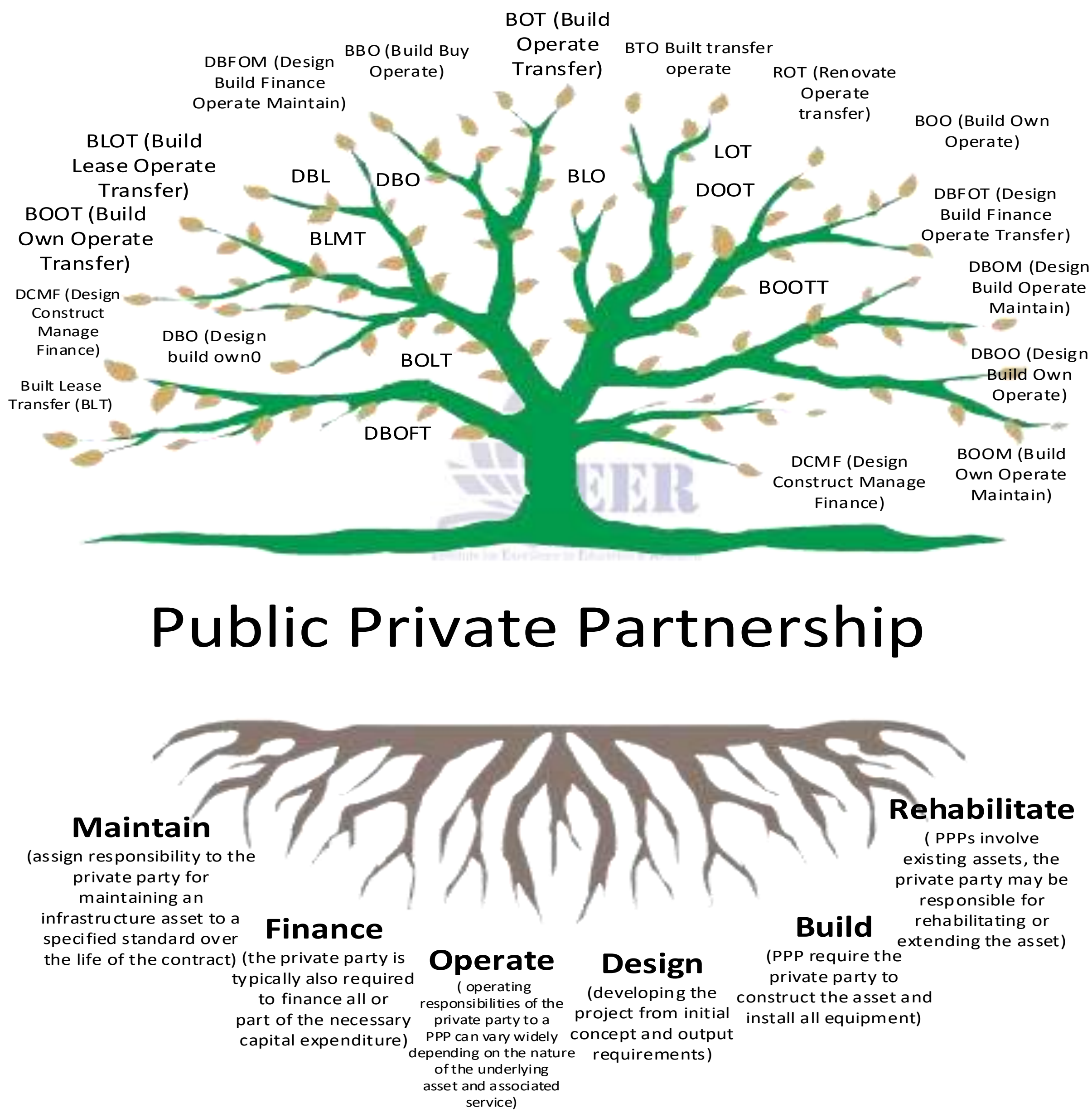

Figure 1. Various PPP contract types / execution modes

The identification and management of risk in large public sector PPP infrastructure projects applies to all project types, from small to large. Rapid urbanization and growing economies have produced a significant need for the execution of new PPP infrastructure projects .(Hasheminezhad et al., 2021) Many countries have come to realize that relying solely on the public sector's funds is not enough to bring about major changes. They involve the private sector in owning, developing, and running national resources and projects to address this issue (Park et al., 2020). This growing trend of partnerships between the public and private sectors aims to secure private financing for projects that used to heavily rely on public funds (Ma et al., 2020).

The combination of a growing need for new developments and a decline in public sector investment has led governments to seek collaborations with private companies for constructing, owning, and managing national resources and projects (Widman, 2016).
Successfully carrying out PPP projects relies on recognizing and evaluating the involved risks, then assigning them to the parties best suited and willing to manage them (Ke et al., 2013b). Considering risks and factors contributing to success is crucial when creating partnerships between the public and private sectors to achieve both societal and economic advantages (Adabre et al., 2021).

Risk is described as the chance of affecting project goals positively or negatively due to uncertainty (Shaygan & Testik, 2019). As risks that were traditionally managed by the government shift to the private sector, the task of distributing risks in PPP projects is often more complex compared to standard public procurement projects.(Cheng et al., 2016) Therefore, recognizing, evaluating, categorizing, allotting, mitigating, and overseeing risks becomes a vital aspect of PPP projects success.(Chou & Lin, 2013)

PPP risk allocation is difficult to accomplish in practice, but it is simple in theory: risks must be assigned to the party best able to manage them (at the lowest cost). VFM has decreased as a result of generic implementations of this principle leading to more or less standardized notions about how risks should be divided between public and private entities (Bing et al., 2005) (Ameyaw et al., 2015b). It also required further guiding principles, such as figuring out which party has more incentive to manage risks in advance and to reduce the financial impact of a risk (Yurdakul et al., 2022).

Although financing public infrastructure using private funds is not a new concept, the PPP has recently helped promote it in several ways. The most notable aspect of this method is the private sector's involvement in public project financing, construction, and operation (Tallaki & Bracci, 2021). The primary benefits of Public-Private Partnerships (PPPs) stem from their ability to optimize financial returns by leveraging the private sector's resources, investments, and providing better infrastructure. The transfer of many risks from the public to the private sector allows for the achievement of all these benefits (Rostiyanti & Pangeran, n.d.)

3. Methodology:

This research aims to rank / prioritize multistage risks and their allocation in various execution modes of PPP infrastructure projects using a quantitative method called Analytical Hierarchical Process (AHP) and a qualitative approach by using *NVivo*. To achieve this ranking, the researchers follow a unique and comprehensive methodology outlined in Figure-2 for AHP, which consists of the following steps: 1) Literature Review the researchers reviewed past research on risk management and prioritization to gather insights. 2) Questionnaire Design a questionnaire is created to collect opinions and experiences from experts in PPP infrastructure.

These experts assess risk parameters, such as probability and impact, related to PPP infrastructure risks. 2) Analytical Hierarchical Process (AHP) AHP is used as a technique for multi-criteria decision-making, allowing us to rank risks within the project based on their severity and likelihood. The answers provided by PPP project experts in the questionnaire are utilized as inputs for the AHP process, enabling pairwise comparisons through a criteria parameter matrix in Microsoft Excel.

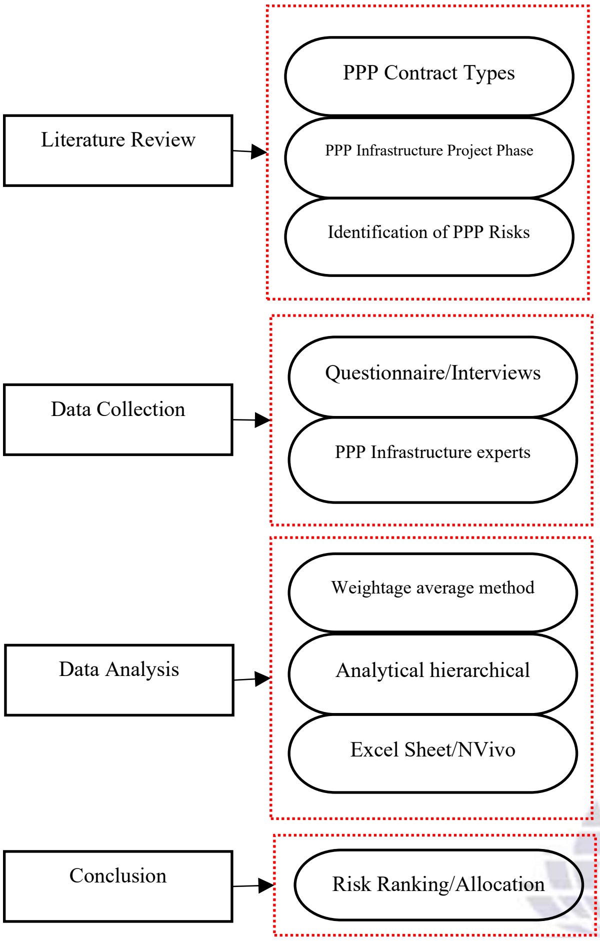

Figure 2 Research methodology for AHP

The researchers studied previous papers on public-private partnership (PPP) infrastructure projects to determine the most common risks. The researchers looked at influential papers and identified 55 various risks for three (03) different categories of modalities. These risks are grouped into seven stages based on different project stages: 1) Planning, Design, and Feasibility Risks (7 subcategories, serial numbers 1-7). 2)Financial Risks (6 subcategories, serial numbers 8-13). 3)Legal and Procurement Risks (13 subcategories, serial numbers 14-25). 4)Operation and Maintenance Risks (5 subcategories, serial numbers 37-41). 5)General and Project Environment Risks (8 subcategories, serial numbers 42-49). 6)Completion and Transfer of Assets Risks (6 subcategories, serial numbers 50-55). 7) (Akhtar et al., 2023). The researchers used a method called Analytical Hierarchical Process (AHP) in Excel to rank these risks. AHP considers the probability and impact of each of the risks on the project. It supports prioritizing the risks effectively during different stages of PPP infrastructure projects. However, the research gap for the ranking of the risks for each of the modalities is fulfilled by using *NVivo* because of the limitation of identifying the experts having hands-on experience in all of the PPP execution modalities. In order to address the gap, semi-structured interviews (open-ended questionnaires) of respondents belong to public sector only were considered and later on by employing the *NVivo* techniques for ranking and allocating the PPP infrastructure risks in their respective execution modes. Figure-3 is showing the methodology adopted for the ranking of the risks through *NVivo* software;

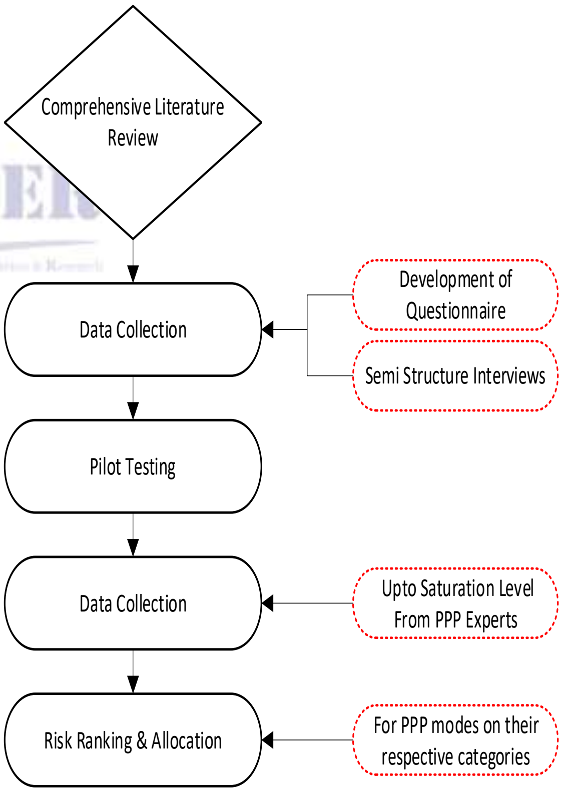

Figure 3 Research methodology for NVivo

3.1. Data Collection:

The researchers collected data from questionnaire by allowing respondents to rate only the risks they had experienced in PPP projects. The researchers provided a list of 55 potential risks and asked respondents to circle only those risks they had encountered. Then, they noted the risk's serial number (from 1 to 55) and rated its impact and probability from 1 to 5, where 1 meant low and 5 meant high. After this exercise, open ended questions were asked form the respondents to address the research gap. The information is gathered from the informants through the in-depth open-ended questions for the ranking and allocation of the risks in their respective PPP infrastructure modes.

Each respondent evaluated only those risks that were common in their field of work for AHP analysis. However, for *NVivo* analysis, the respondents were asked in depth questions. As a result, some risks received higher ratings from respondents, while others received lower ratings based on their likelihood of happening in the project by using weighted average method for AHP analysis. To rank the risks in *NVivo*, the researchers used hierarchy charts based on the respondents' answers to rank the risks in the various execution modes of PPP infrastructure projects.

3.2. Questionnaire Response:

The researchers interviewed and filled the questionnaire from 40 PPP experts and collected quantitative and qualitative data, and an additional 38 respondents filled out a survey form online. The respondents were categorized into two groups: Group-I comprised all respondents who interviewed and filled out online forms for AHP analysis and Group-II included shortlisted 25 respondents from the public sector organization only for *NVivo* analysis on various execution modes of PPP infrastructure Projects. Figure 4, 5 and 6 showing the demographics of the respondents in terms of gender, qualification and organization, respectively.

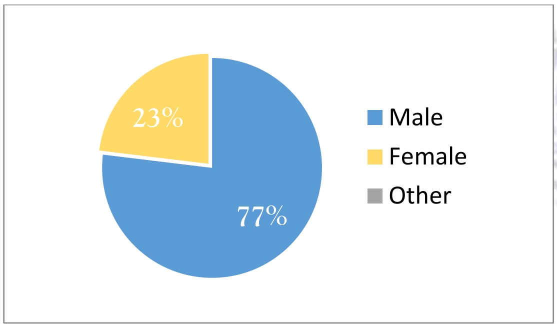

Figure 4 PPP Experts gender Classification

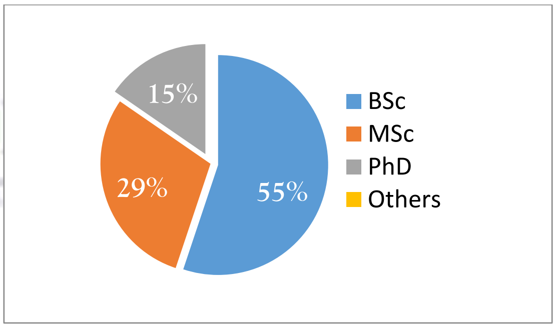

Figure 5 Respondent (PPP Expert) qualification

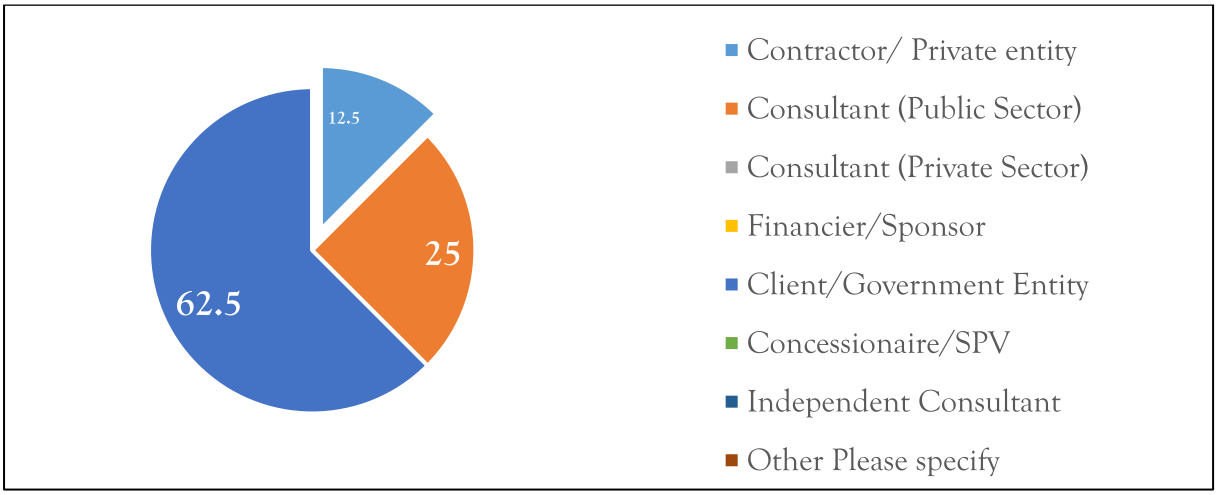

Figure 6 Respondents' organization

The researchers collected data from experts involved in PPP infrastructure projects and respondents sharing their insights. All these respondents were well-qualified and actively engaged in PPP projects.

3.3. Results from the Questionnaire:

During the execution of PPP infrastructure projects, project managers and PPP partners encounter various challenges. These challenges stem from uncertain events, as noted by several PPP experts who shared their perspectives on risks associated with PPP projects. To simplify the questionnaire for the respondents, The researchers categorized the risks into seven categories (Akhtar et al., 2023). Respondents then provided their opinions on the risks they had experience with and those that had a higher likelihood and impact on the project.

Pairwise Comparison in the Questionnaire:

The researchers conducted pairwise comparisons using the Analytical Hierarchical Process (AHP), where the number of comparisons was based on "n," the number of alternatives (risks). The total comparisons were calculated as (n(n-1)/2). s process involved comparing each risk with every other risk. The entire AHP process included the creation of a pairwise matrix, the determination of preferences for each risk over the others (as indicated by PPP experts), calculation of row averages (priority vector), and assessment of the consistency index to ensure the decision's validity.

4. Data Analysis:

Once the researchers gathered quantitative information from experts involved in PPP infrastructure projects, they analyzed the data using an Excel sheet. They recorded the respondents' ratings on the Excel sheet, calculating the average impact and probability for each risk individually. To assess each risk's significance, they used the weighted average method, considering the number of respondents as weights for each risk. The researchers determined the risk probability and impact levels, assigning a preference ranking from 1 to 9 for each risk based on these levels. The researchers also shortlisted the 25 respondents with public sector experience and analyzed the data qualitatively on *NVivo* software.

Analytical Hierarchical Process (AHP):

Analytical Hierarchical Process (AHP) is a decision-making tool (Lyu et al., 2018) that operates within Excel, utilizing responses from respondents to assess and rank 55 identified risks. These risks are categorized into seven distinct risk categories, serving as criteria for the ranking (Akhtar et al., 2023).

According to R.W.Saaty AHP is a method for multi-criteria decision-making, employing pairwise comparisons to rank alternatives. In this approach, criteria are compared by determining preferences. Each risk is measured based on the product of its impact and probability.

Here's a simplified step-by-step process for AHP decision-making as described by the (Taylor, 2016):

1. Creation of a comparison matrix for each risk alternative for each criteria.
2. Synthesize the comparisons matrix by:
   a) Adding the values in each column of the comparison matrices.
   b) Normalizing the matrices by dividing each value in a column by the column's sum, resulting in normalized matrices.
   c) Averaging the values in each row of the normalized matrices to obtain preference vectors.
   d) Combining the preference vectors for each criteria into a preference matrix indicating the preference for each site for each criteria.
3. Develop a comparison matrix for the criteria.
4. Normalizing the matrix by dividing each value in a column by the sum of each column.
5. Determine the preference vector by calculating row averages for the normalized matrix.
6. Calculating overall score for each risk alternative by multiplying the criteria preference vector from step-5 by the criteria matrix (from step-2d).

7. Rank the risk alternatives based on their scores computed in step-6.

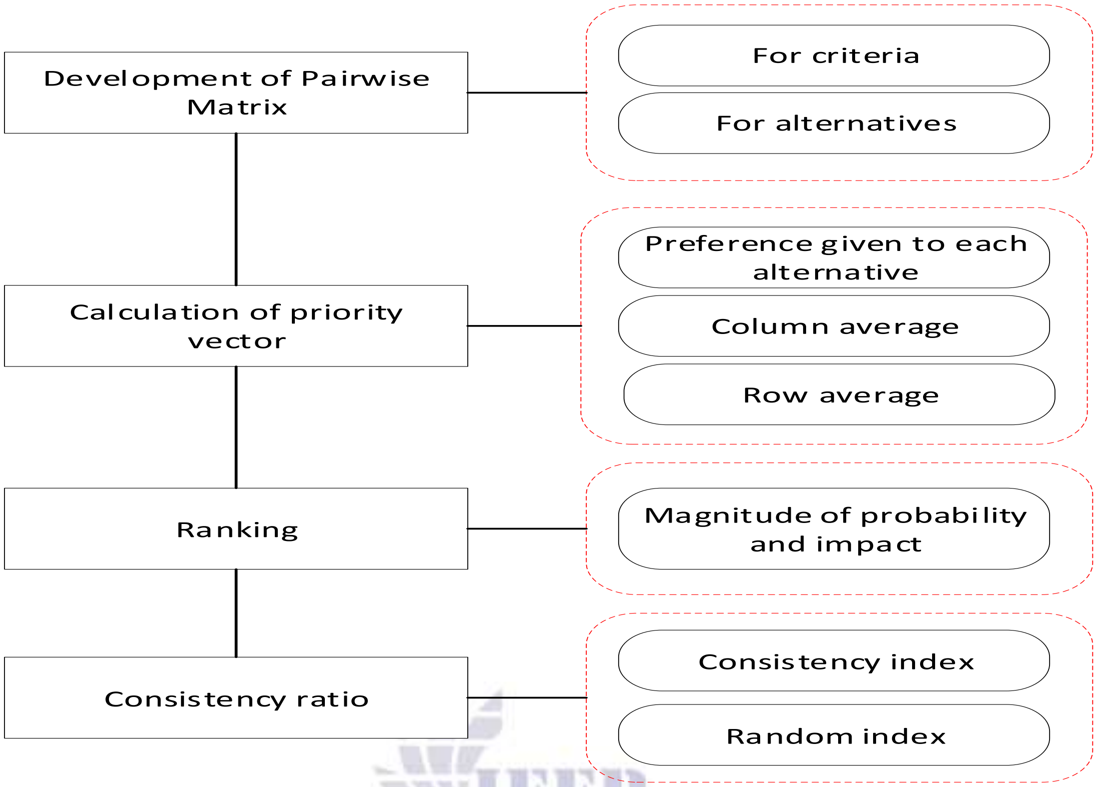

Figure 7 AHP steps flow diagram

In the AHP process, hierarchy created as shown in Figure 8. At Level 1, the main goal of AHP was defined. Moving to Level 2, the researchers established the criteria crucial for making decisions. Finally, at Level 3, the researchers identified the alternatives, which in this case are the 55 risks that they aimed to rank based on their impact and probability within the project. For each of the seven risks categories, pairwise comparison matrix was constructed. Additionally, the researchers created one matrix table, specifically for the criteria. Table-2 illustrates the preference scale used to compare the alternatives, while Table-1 displays various values for the random index based on the size of the matrix.

Table 1 Random index table for consistency

Matrix	RI (Random Index)
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

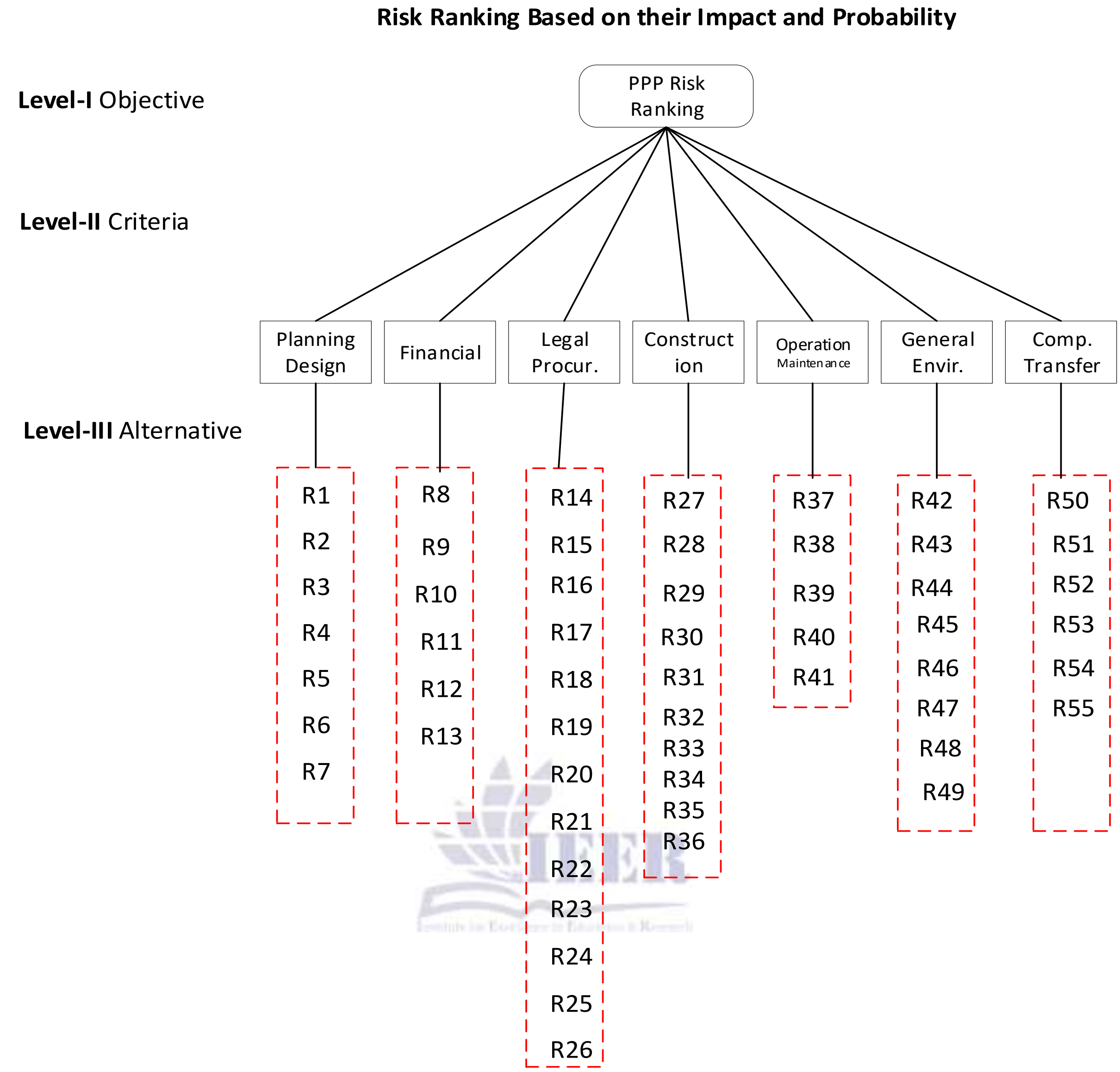

Figure 8 AHP Hierarchy

Pairwise Comparison and Consistency:
AHP uses preference scale for decision maker to give its preference between two parameters pairwise comparison table1. Table 2 AHP preference table for pairwise comparison between to risks

Table 2 Preference scale for pairwise comparison

Rating	Experts Preferences
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very strongly to extremely preferred
9	Extremely preferred

To establish preferences in pairwise risk comparisons, the researchers have designed a questionnaire. To calculate the row averages for criteria, the researchers followed these AHP steps: Sum the values in each column and divide the sum by each entry in the column. Calculate the row average by summing the row entries and dividing by the total number of columns. These steps help in determining the priority vector for each risk.

Table 3 Pairwise comparison according to Criteria

	S1: Planning Design and Feasibility Risks	S2: Financial Risks	S3: Legal and Procurement Risks	S4: Construction & Execution Risks	S5: Operation and Maintenance Risks	S6: General and Project Environment Risks	S7: Completion and Transfer of Assets Risks	**Priority Vector**	**Ranking**
S1: Planning, Design, and Feasibility Risks	1	3	2	0.2	5	3	6	**0.18**	**2nd**
S2: Financial Risks	0.33	1	0.5	0.167	4	1	4	**0.09**	**4th**
S3: Legal and Procurement Risks	0.50	2	1	0.2	5	2	5	**0.13**	**3rd**
S4: Construction & Execution Risks	5.00	5.99	5	1	8	6	8.5	**0.45**	**1st**
S5: Operation and Maintenance Risks	0.20	0.25	0.20	0.13	1	0.25	2	**0.04**	**6th**
S6: General and Project Environment Risks	0.33	1.00	0.50	0.17	4	1	4	**0.09**	**5th**
S7: Completion and Transfer of Assets Risks	0.17	0.25	0.20	0.12	0.50	0.25	1	**0.03**	**7th**

Consistency ratio is calculated by:

Multiplication of pairwise criteria matrix with vector priority

$$\begin{bmatrix} 1 & 5 & 6 & 0.12 & 9 & 6 & 9 \\ 1/5 & 1 & 2 & 0.11 & 6 & 2 & 8 \\ 1/6 & 1/2 & 1 & 0.11 & 5 & 1 & 7 \\ 8 & 8 & 8 & 1 & 9 & 9 & 9 \\ 1/9 & 1/6 & 1/5 & 1/9 & 1 & 0.2 & 4 \\ 1/6 & 1/2 & 1 & 1/9 & 5 & 1 & 7 \\ 1/9 & 1/8 & 1/7 & 1/9 & 1/4 & 1/7 & 1 \end{bmatrix} \times \begin{bmatrix} 0.202 \\ 0.114 \\ 0.076 \\ 0.465 \\ 0.042 \\ 0.076 \\ 0.025 \end{bmatrix} = \begin{bmatrix} 1.61 \\ 0.86 \\ 0.55 \\ 3.78 \\ 0.30 \\ 0.55 \\ 0.19 \end{bmatrix}$$

Divide each element by its corresponding row vector.

$$\begin{bmatrix} 1.61 \\ 0.86 \\ 0.55 \\ 3.78 \\ 0.30 \\ 0.55 \\ 0.19 \end{bmatrix} \div \begin{bmatrix} 0.202 \\ 0.114 \\ 0.076 \\ 0.465 \\ 0.042 \\ 0.076 \\ 0.025 \end{bmatrix} = \begin{bmatrix} 7.95 \\ 7.50 \\ 7.28 \\ 8.13 \\ 7.04 \\ 7.28 \\ 7.35 \end{bmatrix}$$

$$\lambda_{max} = \frac{7.95+7.50+7.28+8.13+7.04+7.28+7.35}{7} = 7.51$$

$$\text{Consistency index} = CI = \frac{(\lambda_{max}-7)}{(7-1)} = \frac{(7.51-7)}{(7-1)} = 0.084$$

Where 7 is number of alternatives / stages in matrix.

Consistency ratio = $\frac{CI}{RI} = \frac{0.084}{1.32} = 0.064$ where RI is the random index from table-1.

Consistency ratio is 0.064 which is less than 0.1 hence AHP decision results are accepted.

In the Analytical Hierarchical Process (AHP), the initial step involves creating a pairwise matrix that compares criteria and alternatives to determine their importance based on preferences. After analyzing table-3 for criteria, it's evident that S4: Construction and execution hold the highest priority vector. Following closely are S1: Planning, design, and feasibility risks, as well as S3: Legal and Procurement risks. On the other hand, S6: General & Project Environmental Risks S5: Operation and maintenance risks, along with S7: Project completion and asset transfer risks, are ranked lower in priority. Figure-9 visually represents the ranking of risk criteria. Using this ranking, then calculate the ranking of sub-category risks. The weightage of each criterion significantly influences the ranking of its respective sub risks, ultimately contributing to the final ranking of alternatives.

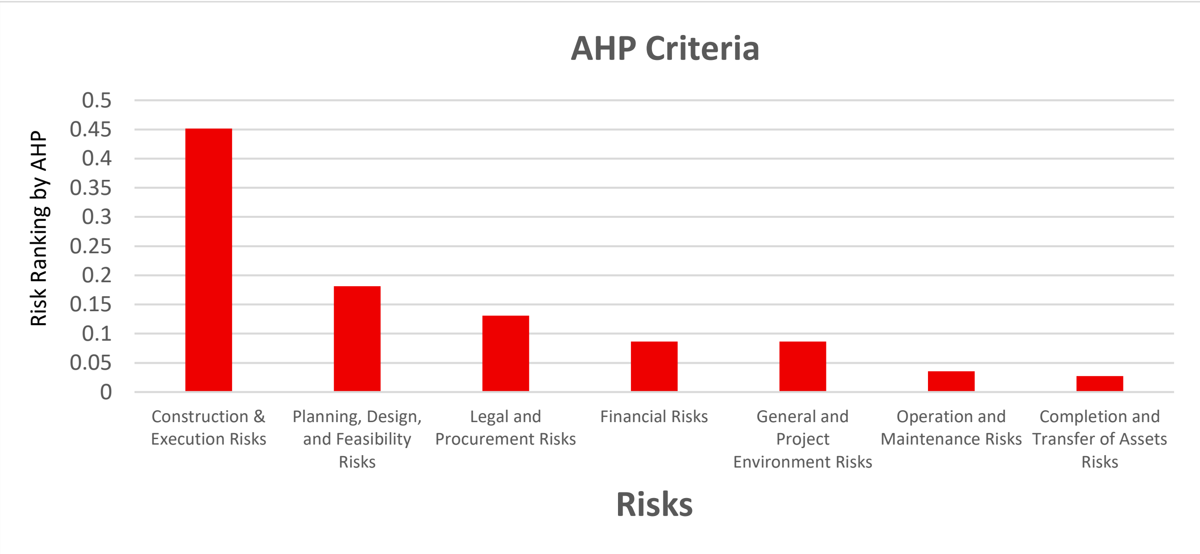

Figure 9 PPP risk criteria ranking graph

Table 4 Overall pairwise Comparison according to alternative

S1: Planning design and feasibility risks									
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**Priority Vector**	**Ranking**
R1	1	0.5	2	0.5	3	2	2	**0.157**	**3rd**
R2	2	1	3	0.5	3	3	2	**0.214**	**2nd**
R3	**0.5**	**0.33**	1	0.33	2	2	0.5	**0.091**	**5th**
R4	**2**	**2**	3	1	4	3	3	**0.288**	**1st**
R5	**0.33**	**0.33**	**0.5**	**0.25**	1	0.5	0.33	**0.052**	**7th**
R6	**0.5**	**0.33**	**0.5**	**0.33**	**2**	1	0.5	**0.075**	**6th**
R7	**0.5**	**0.5**	**2**	**0.33**	**3**	**2**	1	**0.123**	**4th**

$$\lambda_{max} = 7.283$$
$$\text{Consistency index} = CI = 0.047$$
$$\text{Consistency ratio} = \frac{CI}{RI} = 0.036$$

Consistency ratio is 0.036 which is less than 0.1 hence AHP decision results are accepted.

The stage of risks related to S1: Planning, design, and feasibility comprises seven sub risks. These risks are identified during the initial phase of a PPP project, which is the planning and design stage. If any of these risks occur, they can negatively impact the project's scope and cost. Improper designs are quite common and can be detrimental.

In the AHP ranking, R4: Improper Preliminary Survey is identified as the highest-ranking risk in this stage, followed by R2: Land Acquisition and Compensation, R1: Improper Design and Technical Study risks, R7: Poor cost estimation, R3: Required initial approvals for a feasibility study, R6: Multilateral agencies and stakeholders' involvement and R5: Inherent risks to conceiving PPP projects respectively. R2 and R3 risks are frequently encountered in PPP projects, significantly affecting the project's viability if not properly addressed or transferred to a partner who can handle them effectively. The availability of land is the responsibility of the government to ensure it is accessible for the project. Figure10 illustrates the ranking of these risks graphically.

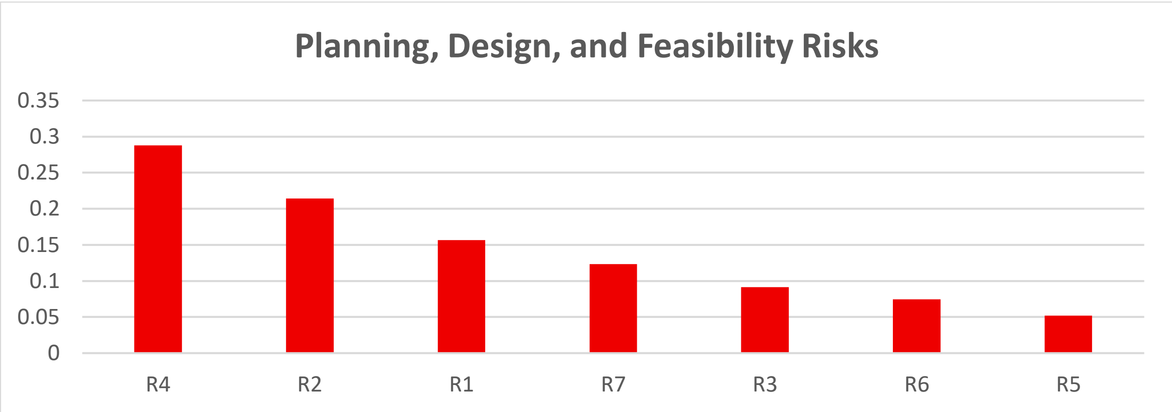

Figure 10 Planning, Design and Feasibility Risks Ranking

In the *NVivo* hierarchy chart analysis for risks preference of the S1:Planning, Design and feasibility phase of the PPP infrastructure projects, R7:Poor cost estimation has been identified as the most preferred risk for all three categories of PPP infrastructure projects, followed by R1:Improper Design & Technical Study, R3:Required initial approvals for a feasibility study, R2:Land Acquisition & Compensation, R5:Inherent risks to conceiving PPP projects, R6:Multilateral Agencies & Stakeholders' Involvement and R4:Improper Preliminary Survey respectively. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A. The following Figure-11 of *NVivo* hierarchy chart shows the risk preference in Planning, Design and Feasibility risk phase.

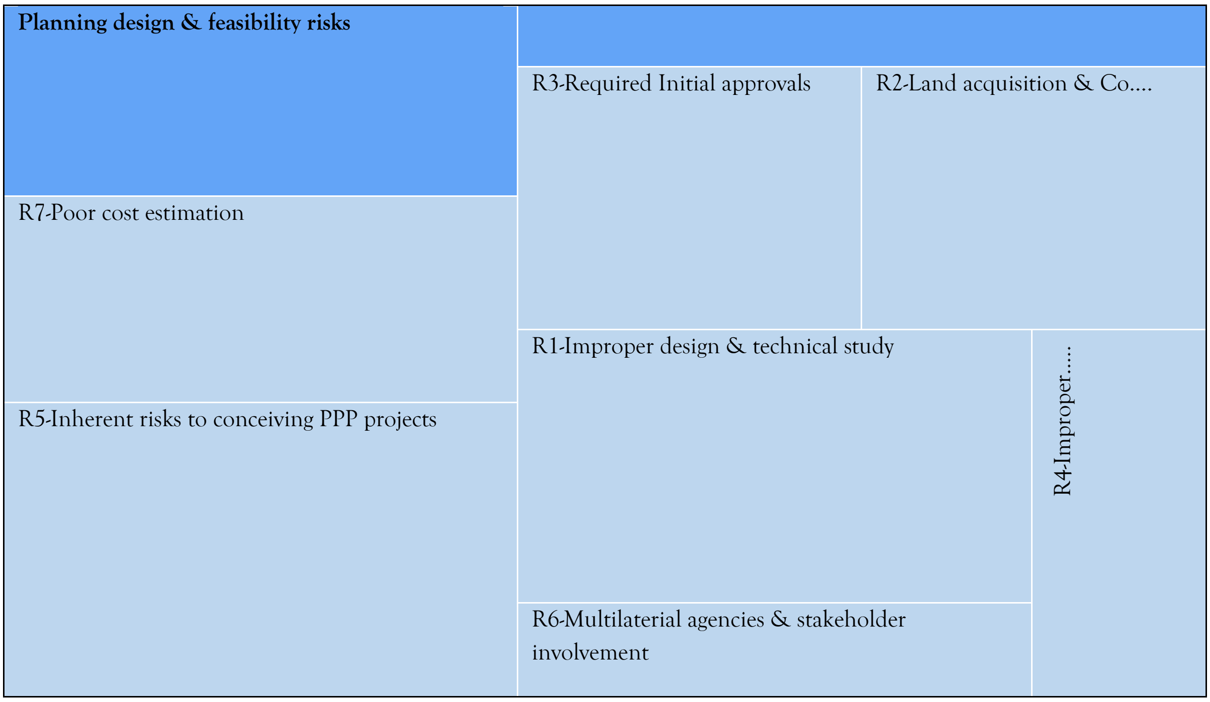

Figure .11 NVIVO Hierarchy Chart for Planning, Design and Feasibility Risks for all types of PPP Category.

In the *NVivo* hierarchy chart analysis for risks preference of the Financial risks of the PPP infrastructure projects, R8: Macroeconomic variables has been identified as the most preferred risk for all three categories of PPP infrastructure projects, followed by R9:Availability of finance, R10:Fulfilment of commitments with financial institutes, R11:Revenue shortfall, R12:Financial Rate of Returns on Investment, R13Financial Insolvency of Host Government respectively. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A. The following Figure-12 of *NVivo* hierarchy chart shows the risk preference in financial risks category.

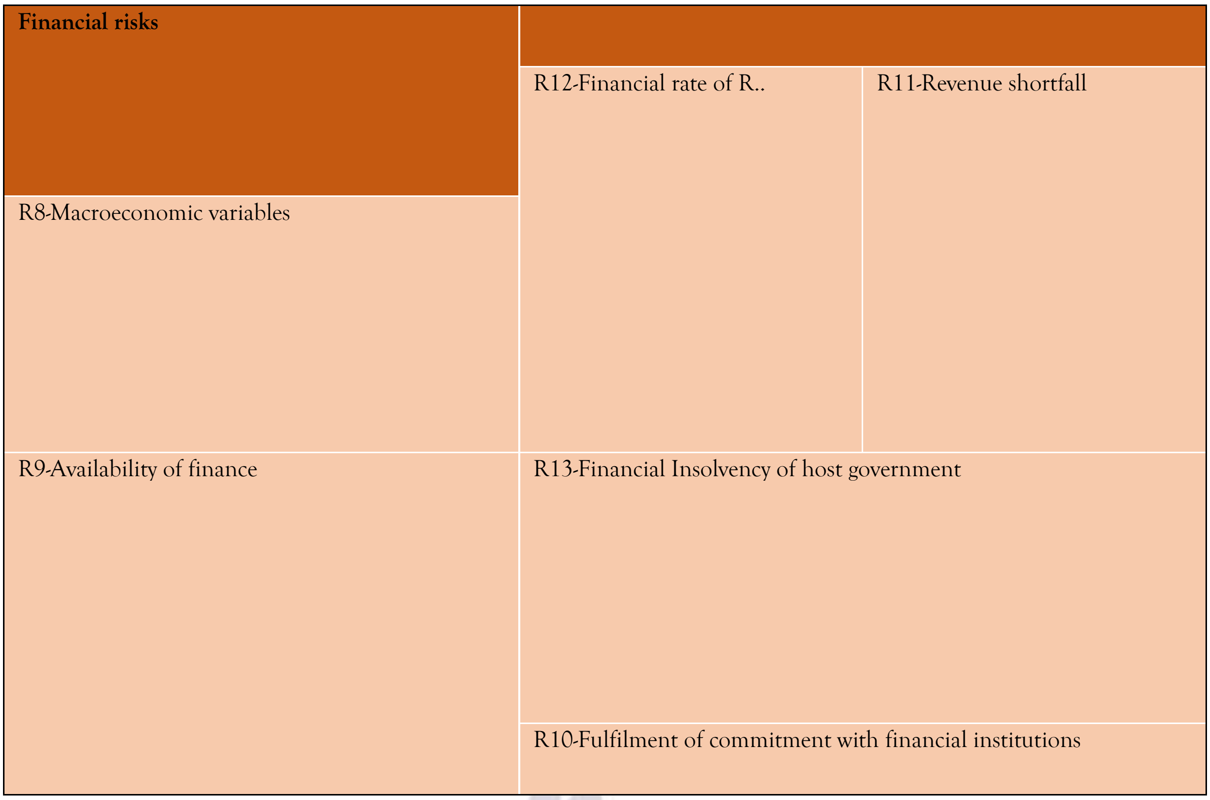

Figure .12 NVIVO Hierarchy Chart for Financial Risks for all types of PPP Category.

Table 5 Overall pairwise Comparison according to alternative

S2: Financial risks								
	R8	**R9**	**R10**	**R11**	**R12**	**R13**	**Priority Vector**	**Ranking**
R8	1	2	2	0.5	0.5	3	1	3rd
R9	**0.5**	1	2	0.5	0.5	3	**0.5**	4th
R10	**0.5**	**0.5**	1	0.5	0.5	3	**0.5**	5th
R11	**2**	**2**	**2**	1	2	3	**2**	2nd
R12	**2**	**2**	**2**	**0.5**	1	3	**2**	1st
R13	**0.33**	**0.33**	**0.33**	**0.33**	0.33	1	**0.33**	6th

$$\lambda_{max} = 6.229$$

$$\text{Consistency index} = CI = 0.046$$

$$\text{Consistency ratio} = \frac{CI}{RI} = 0.037$$

Consistency ratio is 0.037 which is less than 0.1 hence AHP decision results are accepted.

Financial risks consist of six subcategories. In the AHP ranking, the R12: Financial rate of return on investment is rated as the most significant, followed by R11: Revenue shortfall, R8: Macroeconomic variables, R9: Availability of finance, R10: Fulfilment of commitments with financial institutes and R13: Financial insolvency of the host government respectively. Conducting a thorough preliminary feasibility survey for the project is crucial to mitigate financial risks. Often, projects go beyond their budget due to inadequate estimation of project costs and macroeconomic variables like the internal rate of return (IRR) on investment and inflation trend forecasts in the country. The graph provides a visual representation of this ranking.

Figure 11 Overall pairwise Comparison according to alternative financial risk

Table 6 Pairwise Comparison

S3: Legal and Procurement Risks														
	R14	**R15**	**R16**	**R17**	**R18**	**R19**	**R20**	**R21**	**R22**	**R23**	**R24**	**R25**	**R26**	**Priority Vector**	**Ranking**
R14	**1**	2	2	2	2	2	0.5	4	2	0.5	1	2	2	**0.10**	**3rd**
R15	0.5	**1**	0.5	0.5	0.5	0.5	0.3	3	0.5	0.333	0.5	0.5	0.5	**0.038**	**12th**
R16	0.5	2	**1**	1	2	2	0.3	4	1	0.5	0.5	0.5	1	**0.064**	**7th**
R17	0.5	2	1	**1**	2	2	0.3	4	1	0.5	0.5	0.5	1	**0.064**	**8th**
R18	0.5	2	0.5	0.5	**1**	1	0.3	3	0.5	0.33	0.5	0.5	0.5	**0.045**	**10th**
R19	0.5	2	0.5	0.5	1	**1**	0.3	3	0.5	0.33	0.5	0.5	0.5	**0.045**	**11th**
R20	2	3	3	3	3	3	**1**	5	3	2	2	2	3	**0.164**	**1st**
R21	0.25	0.33	0.25	0.25	0.3	0.3	0.2	**1**	0.25	0.2	0.25	0.25	0.25	**0.019**	**13**
R22	7	2	1	1	2	2	0.3	4	**1**	0.5	0.5	0.5	1	**0.094**	**5th**
R23	2	3	2	2	3	3	0.5	5	2	**1**	2	2	2	**0.129**	**2nd**
R24	1	1	2	2	2	2	0.5	4	2	0.5	**1**	2	2	**0.096**	**4th**
R25	0.5	0.5	2	2	2	2	0.5	4	2	0.5	0.5	**1**	2	**0.082**	**6th**
R26	0.5	0.5	1	1	2	2	0.33	4	1	0.5	0.5	0.5	**1**	**0.059**	**9th**

$$\lambda_{max} = 13.710$$

$$\text{Consistency index} = CI = 0.059$$

$$\text{Consistency ratio} = \frac{CI}{RI} = 0.037$$

Consistency ratio is 0.037 which is less than 0.1 hence AHP decision results are accepted.

In the realm of legal and procurement risks, there are thirteen subcategories. According to the AHP ranking, the highest-ranked risk is R20:Legally Weak Partnership or Strategic Alliance followed by R23:Lack of Flexibility in Contracts, R14: Ownership of assets, R24: Market demand for assets, R22: Tenant risks, R25: Legal aspects of the property, R16: Insolvency of the public or private sector, R17: Third-party reliability, R18: Institutional nature arrangement, R19: Encumbrances of land, R15: Change in Law and R21: Inefficient procurement process respectively

Given the extensive and prolonged contractual agreements involving multiple parties in PPP projects, third parties play a crucial role. However, financial resource availability can often be limited. To mitigate these risks, it's important to consider the financial stability of the funding party and the working experience of the third party during the preliminary survey of the PPP project before it is awarded by the client. Following Figure 14 shows the graphical representation of the S3: Legal and Procurement risks.

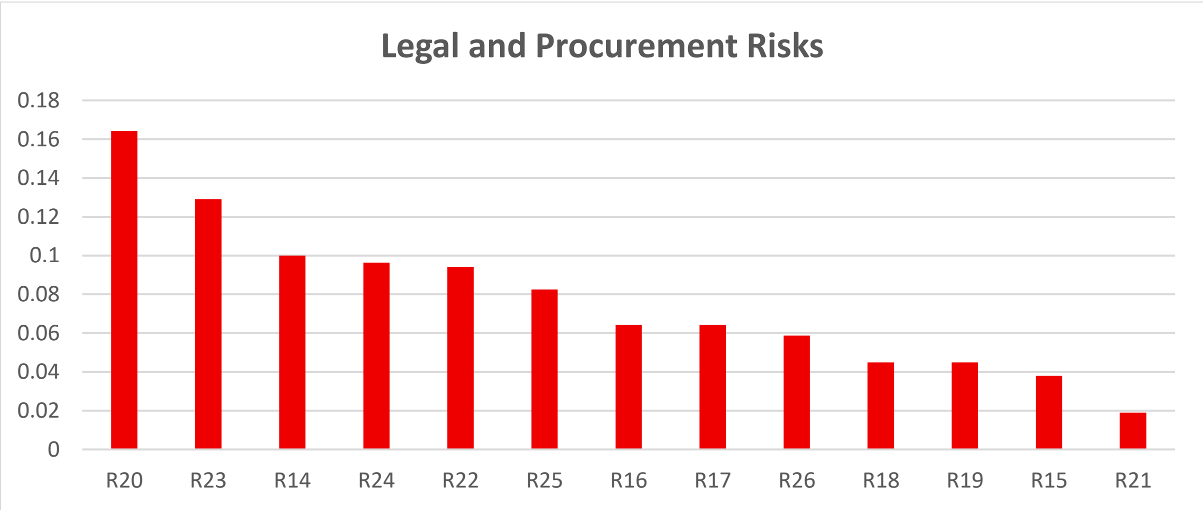

Figure 14 Legal and Procurement Risks ranking

In the *NVivo* hierarchy chart analysis for risks preference of the Legal & Procurement Risks stage of the PPP infrastructure projects shows variance in risks preferences for all three execution categories of the PPP projects.

Following Figures 15, 16 &17 are showing the risks preferences hierarchy chars for PPP execution modes like DBFOT/BOT type of PPP Contracts, Lease/Afterimage/BLT type of PPP Contracts and Ownership/BOOT type of PPP Contracts respectively;

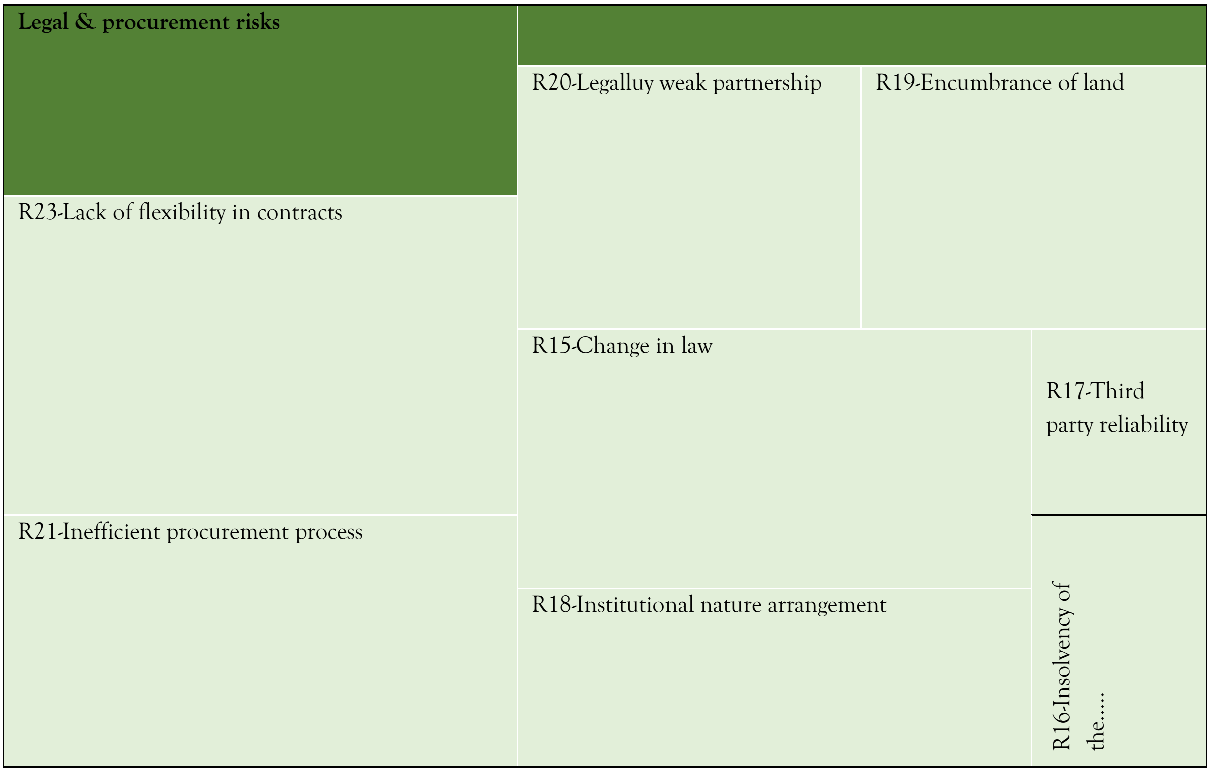

Figure .15 NVivo Hierarchy Chart for Legal & Procurement Risk for DBFOT/BOT type of PPP Contracts Category.

The above Figure-15 hierarchy chart shows the Legal & Procurement risk category preference as R23: Lack of flexibility in contracts is the most preferred risk in the DBFOT/BOT type of PPP Contracts category followed by R15: Change in Law, R20: Legally weak partnership or strategic alliance, R19: Encumbrances of land, R21:Inefficient procurement Process, R18:Institutional nature arrangement, R17:Third-party reliability and R16:Insolvency of the Public or Private sector. Figure-16 below shows the risk preference of same project stage but in Lease/Afferemage/BLT type of PPP Contracts category. The risk preferences vary in this category. R22: Tenant risks is most preferred risk in this category followed by R24:Market demand of assets, R25:Legal aspects of the property, R23: Lack of flexibility in contracts, R15:Change in Law, R20:Legally weak partnership or strategic alliance R21:Inefficient procurement Process, R18:Institutional nature arrangement, R17:Third-party reliability and R16:Insolvency of the Public or Private sector. Figure-17 below shows the risk preference of same project stage but in the Ownership/BOOT type of PPP Contracts category. The risk preferences vary in this category. R14: Ownership of assets is most preferred risk in this category followed by R26: Expropriation, R15:Change in Law, R23: Lack of flexibility in contracts R20:Legally weak partnership or strategic alliance R21:Inefficient procurement Process, R18:Institutional nature arrangement, R17:Third-party reliability and R16:Insolvency of the Public or Private sector. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A.

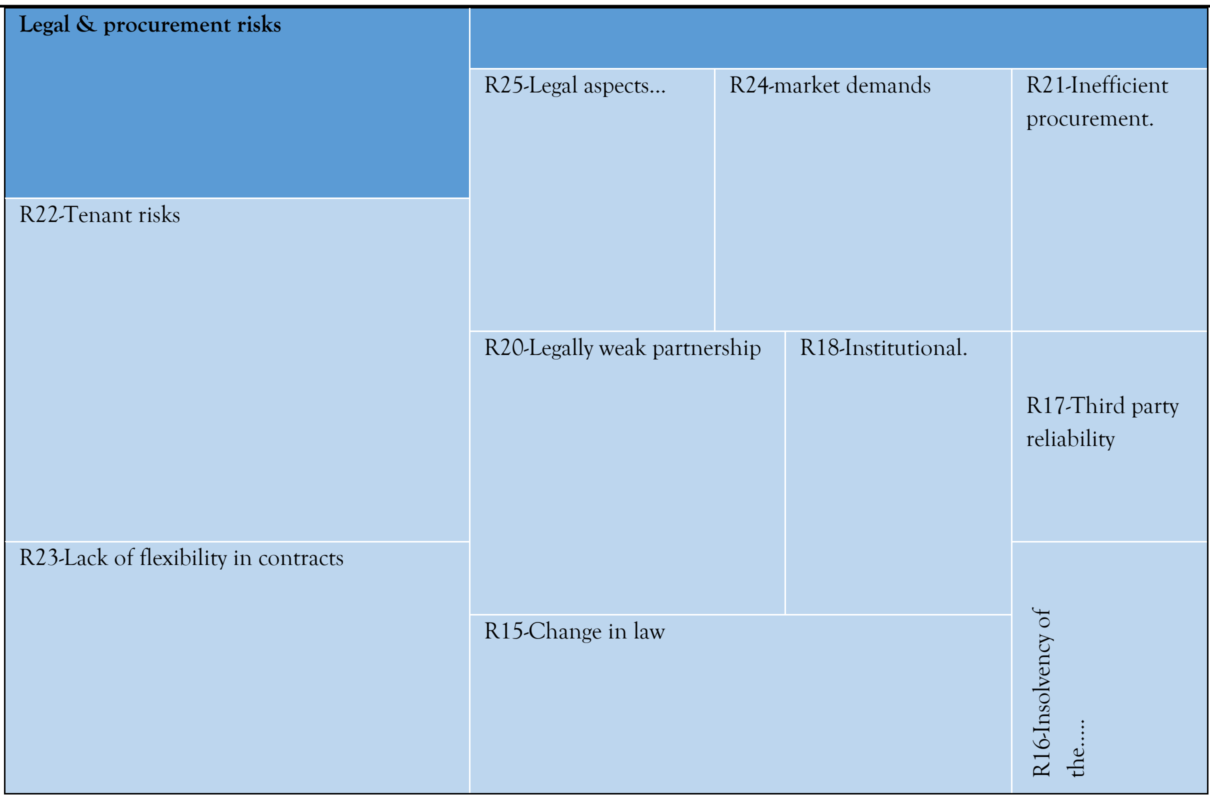

Figure .16 NVivo Hierarchy Chart for Legal & Procurement Risk for Lease/Afferemage/BLT type of PPP Contracts

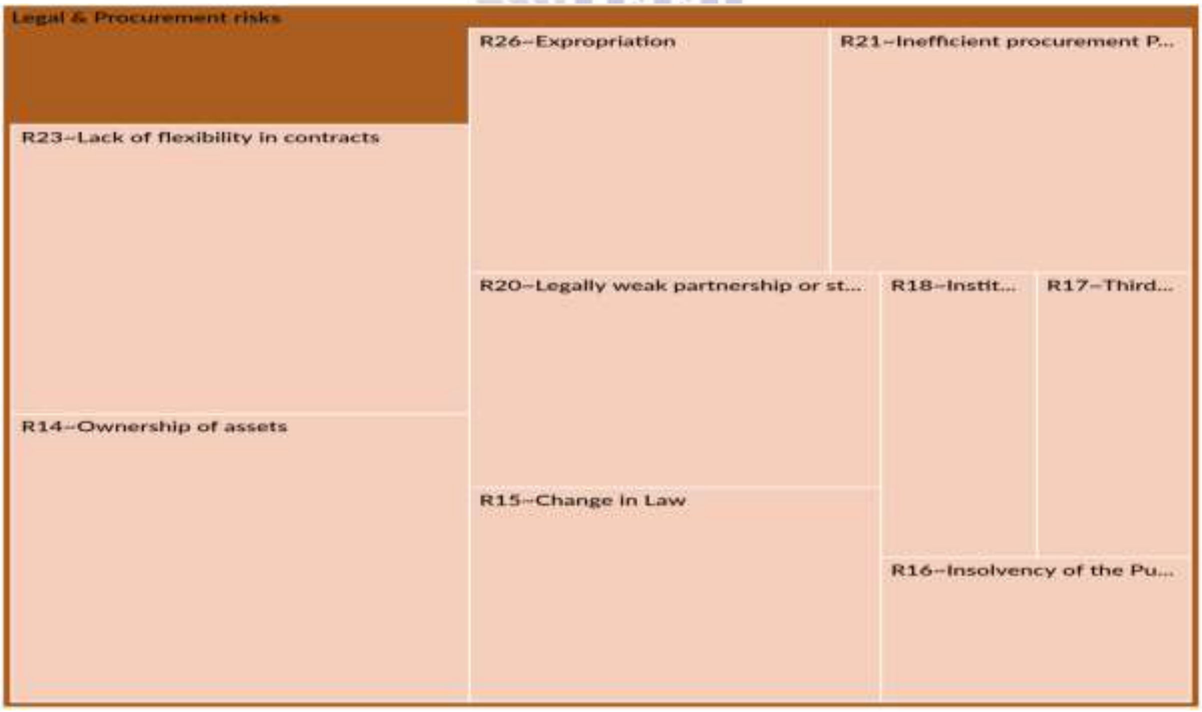

Figure. 17 NVivo Hierarchy Chart for Legal & Procurement Risk for Ownership/BOOT type of PPP Contracts

Table 7 Overall pairwise Comparison according to alternative

S4: Construction and execution risks												
	R27	R28	R29	R30	R31	R32	R33	R34	R35	R36	Priority Vector	Ranking
R27	1	3	2	2	0.5	4	2	3	3	3	0.173	2nd
R28	0.3	1	0.5	0.5	0.3	2	0.5	2	2	0.5	0.066	7th
R29	0.5	2	1	2	0.5	3	2	2	3	2	0.130	3rd
R30	0.5	2	0.5	1	0.5	3	2	2	3	2	0.114	4th
R31	2	3	2	2	1	4	3	3	4	3	0.213	1st
R32	0.25	0.5	0.3	0.3	0.25	1	0.3	0.5	0.5	0.5	0.035	10th
R33	0.5	2	0.5	0.5	0.3	3	1	2	2	2	0.092	5th
R34	0.3	0.5	0.5	0.5	0.3	2	0.5	1	2	0.5	0.057	8th
R35	0.3	0.5	0.3	0.3	0.25	2	0.5	0.5	1	0.5	0.044	9th
R36	0.3	2	0.5	0.5	0.3	2	0.5	2	2	1	0.075	6th

$$\lambda_{max} = 10.431$$

$$\text{Consistency index} = CI = 0.048$$

$$\text{Consistency ratio} = \frac{CI}{RI} = 0.032$$

The consistency ratio is 0.032 which is less than 0.1; hence AHP decision results are accepted.

In the domain of S4: Construction and execution, there are ten subcategories of risks. According to the AHP ranking, the top-ranked risk is R31:Scope Creep followed by R27:Poor Quality, R29: Unforeseen construction cost overrun, R30: Availability of land for use, R33: Delay in a construction period, R36: Shifting of utilities, R28: Unproven engineering techniques, R34: Availability of labor and material, R35: Protection of geological and historical objects and R32: Inadequate health and safety measures risks respectively.

The world is evolving swiftly with advancements in new machinery and technologies. Traditional engineering techniques and technology can affect the quality and scope of a project. To mitigate these risks, it's crucial to ensure access to the latest technology and machinery before commencing the execution of a PPP project. Following Figure-18 is showing the ranking of risks in S4: Construction & Execution Risks graphically.

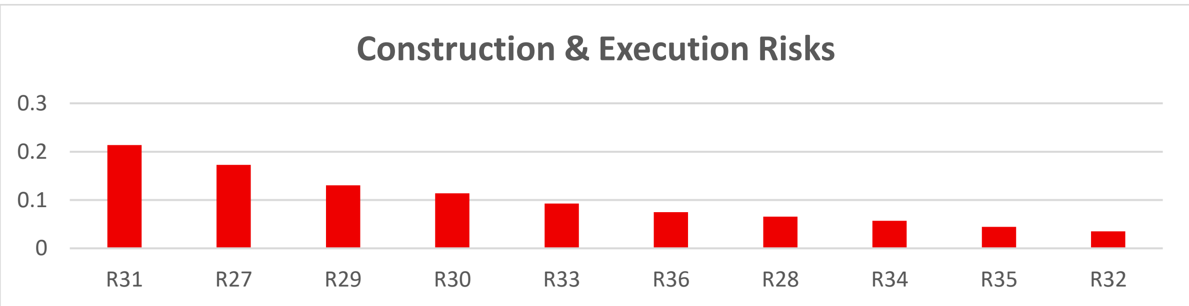

Figure 18 Construction & Execution Risks

Following Figure-19 shows the NVivo hierarchy chart analysis for risks preference of the Construction & Execution risks of the PPP infrastructure projects, R31:Scope creep has been identified as the most preferred risk for all three categories of PPP infrastructure projects, followed by R27:Poor quality, R29:Unforeseen construction cost overruns, R30:Availability of land for use, R28:Unproven engineering techniques, R32:Inadequate health and safety measures, R33:Delay in a construction period, R34:Availability of Labor and material, R36:Shifting of utilities, and R35:Protection of geological & historical objects respectively. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A.

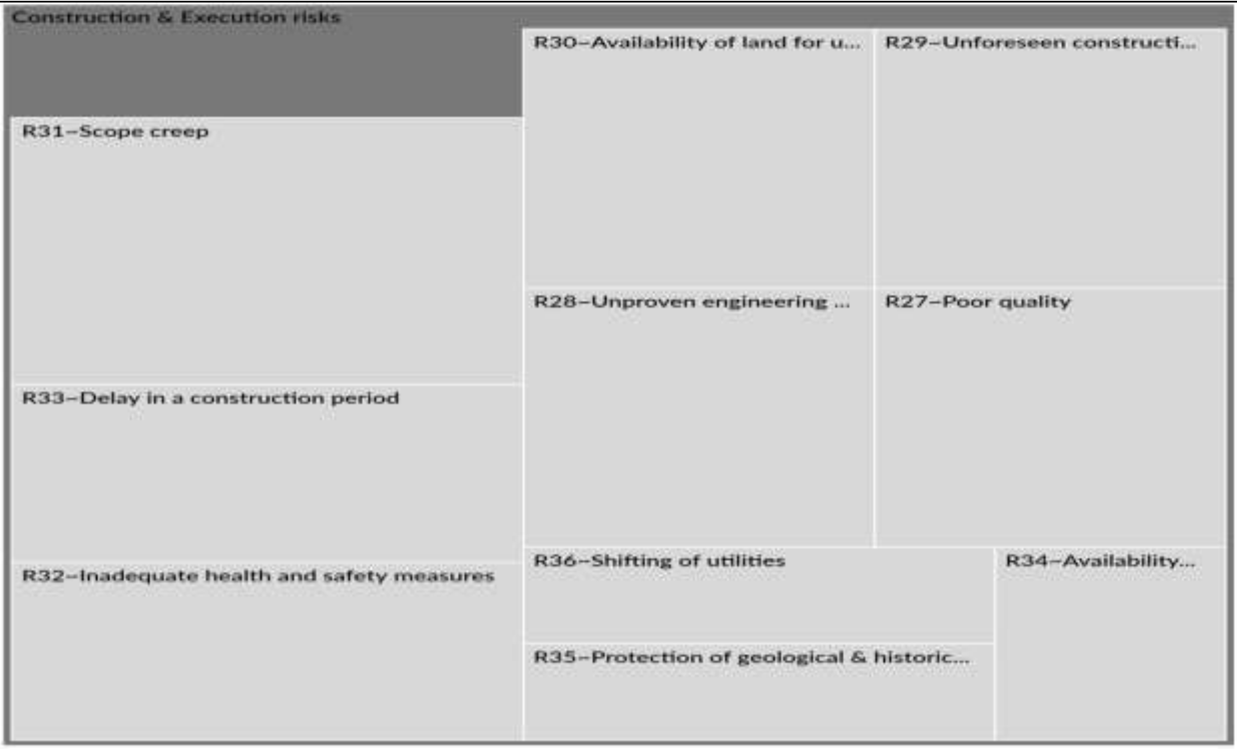

Figure 19 NVivo Hierarchy Chart for Construction & Execution Risk for all types of PPP Contracts categories

Table 8 Overall pairwise Comparison according to alternative

S5: Operation and maintenance risks							
	R37	R38	R39	R40	R41	Priority Vector	Ranking
R37	1	4	4	2	2	**0.372**	**1st**
R38	0.25	1	0.5	0.25	0.33	**0.067**	**5th**
R39	0.25	2	1	0.25	0.33	**0.089**	**4th**
R40	0.5	4	4	1	2	**0.282**	**2nd**
R41	0.5	3	3	0.5	1	**0.191**	**3rd**

$$\lambda_{max} = 5.144$$

Consistency index = CI = 0.036

$$\text{Consistency ratio} = \frac{CI}{RI} = 0.032$$

Consistency ratio is 0.032 which is less than 0.1 hence AHP decision results are accepted.

Within the operation and maintenance risk category, there are five subcategories. According to the AHP ranking, R37:Operation and Maintenance is ranked the highest, followed by R40: The uncertainty in rent prices, R41:Toll Slippages, R39: Frequency of maintenance and R38: Demand and revenue shortfall respectively. The variation in prices is often caused by macroeconomic variables and the financial stability of a country. In PPP road projects, R41:Toll Slippages is a common issue. To mitigate this risk, implementing closed entry and exit points for roads is a viable solution

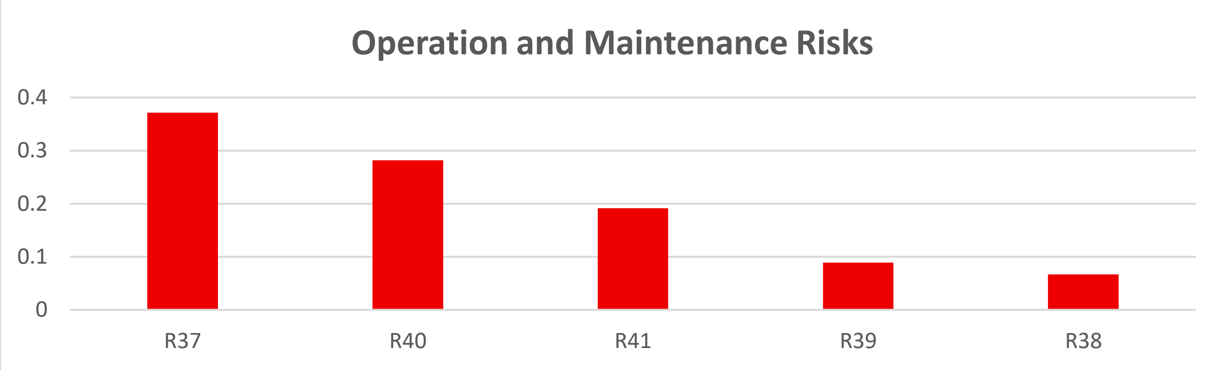

Figure 20 Operation and Maintenance Risks

Figure 21 NVivo Hierarchy Chart for Operations & Maintenance Risk for all types of PPP Contracts categories

Above Figure-21 shows the *NVivo* hierarchy chart analysis for risks preference of the Operations & Maintenance risks of the PPP infrastructure projects, R37: Operation & Maintenance has been identified as the most preferred risk for all three categories of PPP infrastructure projects, followed by R38: Demand & revenue shortfall, R41:Toll slippages and R39:Frequency of maintenance respectively. R40: The uncertainty in rent prices falls in the Lease/Affermage/ BLT Types of PPP contracts category only and ranked second in the respective project stage. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A.

Table 9 Overall pairwise Comparison according to alternative

S6: General & Project Environment risks										
	R42	R43	R44	R45	R46	R47	R48	R49	Priority Vector	Ranking
R42	1	0.33	4	3	0.2	0.5	2	0.5	0.083	5th
R43	3	1	5	4	0.33	2	4	3	0.19	2nd
R44	0.25	0.2	1	0.33	0.143	0.25	0.333	0.25	0.027	8th
R45	0.33	0.25	3	1	0.167	0.33	0.5	0.33	0.045	7th

R46	5	3	6.99	5.98	1	4	6	4	**0.35**	**1st**
R47	2	0.5	4	3	0.25	1	3	2	**0.12**	**3rd**
R48	0.5	0.25	3	2	0.16	0.3	1	0.33	**0.05**	**6th**
R49	2	0.33	4	3	0.25	0.5	3	1	**0.107**	**4th**

$$\lambda_{max} = 8.521$$
$$\text{Consistency index} = CI = 0.074$$
$$\text{Consistency ratio} = \frac{CI}{RI} = 0.053$$

Consistency ratio is 0.053 which is less than 0.1 hence AHP decision results are accepted.
S6: General and project environment risks have eight sub categories risk AHP ranked R46:lack of R&D in the PPP regime risk as first followed by R43: Political instability, R47: Natural disasters or force majeure events, R49: Inherent risks, R42: Corruption, R48: Transfer of technology, R45: Ground and weather conditions and R44: Environmental permits respectively. Following Figure 22 shows the graphical ranking of the general and project environment risks.

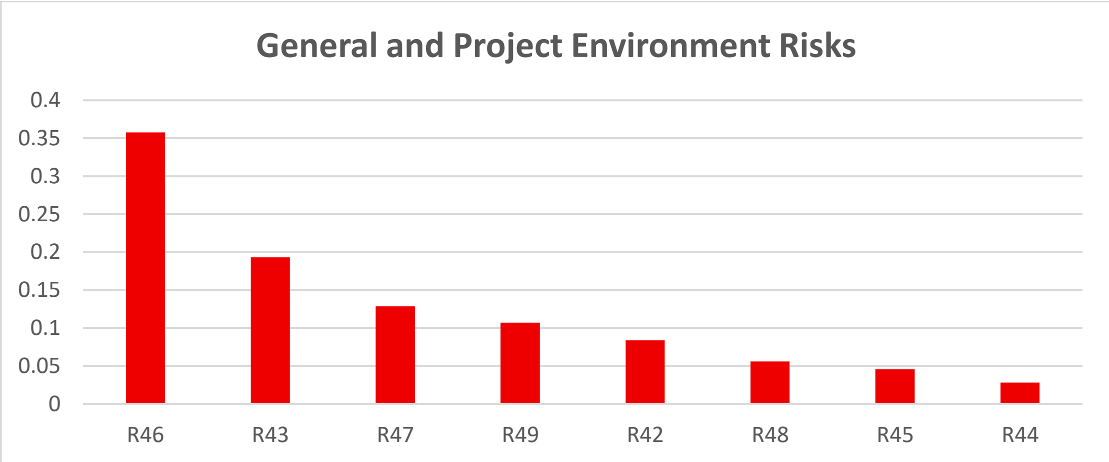

Figure 22 General and Project Environment Risks

Following Figure23 shows the *NVivo* hierarchy chart analysis for risks preference of the General/Project Environment risks for all types of execution modes categories of PPP infrastructure projects, R42:Corruption has been identified as the most preferred risk for all three categories of PPP infrastructure projects, followed by R43:Political instability, R46:Lack of R&D in the PPP regime, R47:Natural disasters or Force majeure events, R49:Inherent risks, R45:Ground and weather conditions, R44:Environmental permits and R48:Transfer of technology respectively. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A

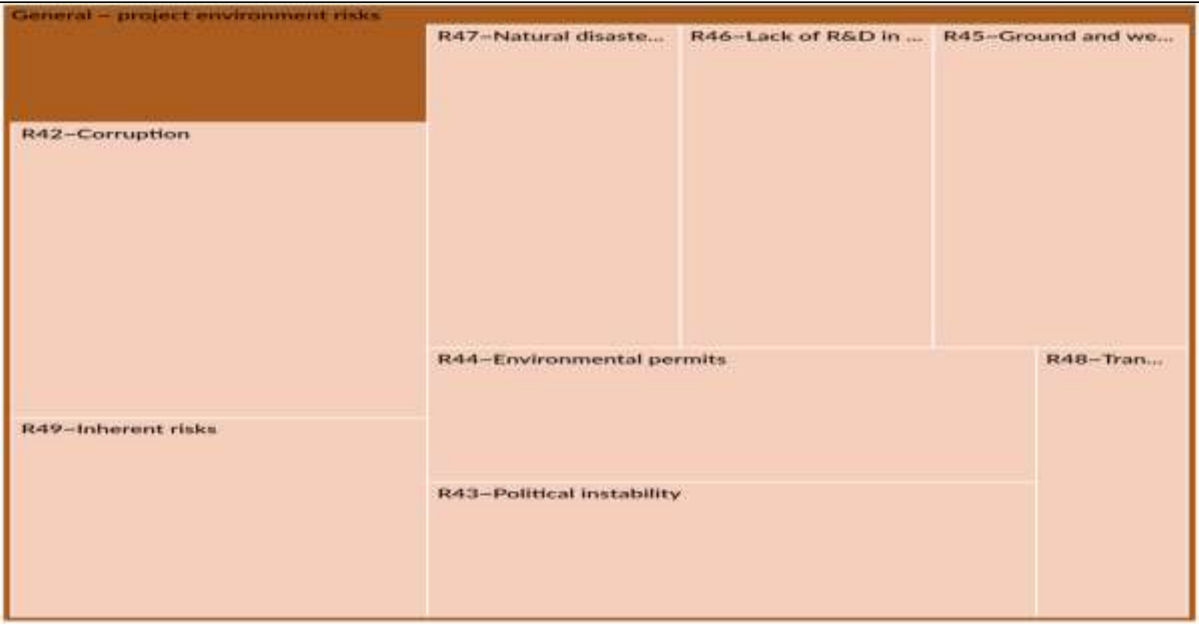

Figure 23 NVivo Hierarchy Chart for General/ Project Environment Risk for Ownership/BOOT types of PPP Contracts category

Table 10 Overall pairwise Comparison according to alternative

S7: completion and transfer of project assets risks								
	R50	**R51**	**R52**	**R53**	**R54**	**R55**	**Priority Vector**	**Ranking**
R50	1	2	0.33	0.33	2	0.33	0.101	4th
R51	**0.5**	1	0.25	0.25	2	0.33	0.073	5th
R52	**3**	**4**	1	0.5	4	2	0.257	2nd
R53	**3**	**4**	**2**	1	4	2	0.324	1st
R54	**0.5**	**0.5**	**0.25**	**0.25**	1	0.33	0.057	6th
R55	**3**	**3**	**0.5**	**0.5**	3	1	0.188	3rd

$$\lambda_{max} = 6.228$$

Consistency index = CI = 0.046

$$\text{Consistency ratio} = \frac{CI}{RI} = 0.037$$

Consistency ratio is 0.037 which is less than 0.1 hence AHP decision results are accepted. Completion and transfer of assets have six sub categories risk AHP ranked R53 Completion of project:, R52: Depreciation of asset, R55: Asset maintenance R50: Project transfer risks,R51: Residual value risks, R54:Asset obsolescence respectively. Following Figure24 shows the graphical representation of S7: Completion & Transfer of Assets Risks.

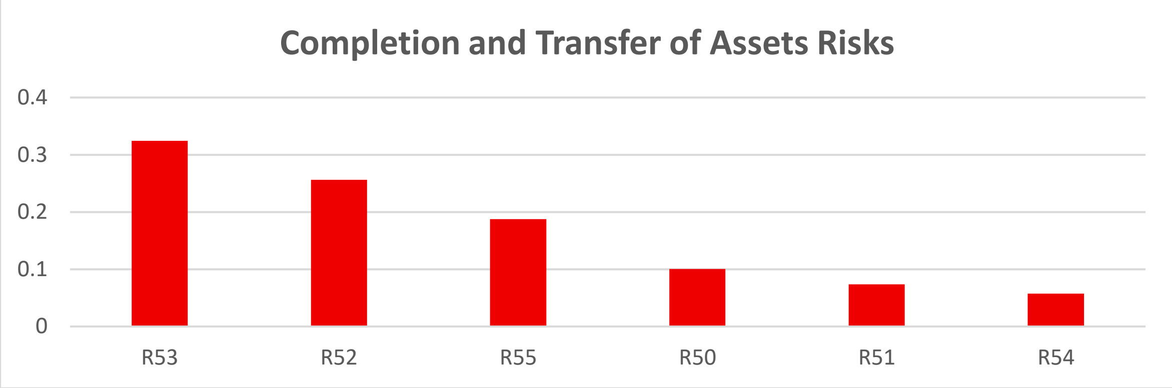

Figure 24 Completion and Transfer of Assets Risks

Following Figure-25 shows the *NVivo* hierarchy chart analysis for risks preference of the Completion / Asset Transfer risks for Ownership/BOOT types of PPP infrastructure projects, R50:Project transfer risks and R53:Completion of project have been identified as the most preferred risks for all three categories of PPP infrastructure projects, followed by R55:Asset maintenance, R51:Residual Value Risks, R52:Depreciation of asset and R54:Asset obsolescence respectively. Moreover, the preferred risk allocation of each risk from the public perspective is also outlined in the Appendix-A.

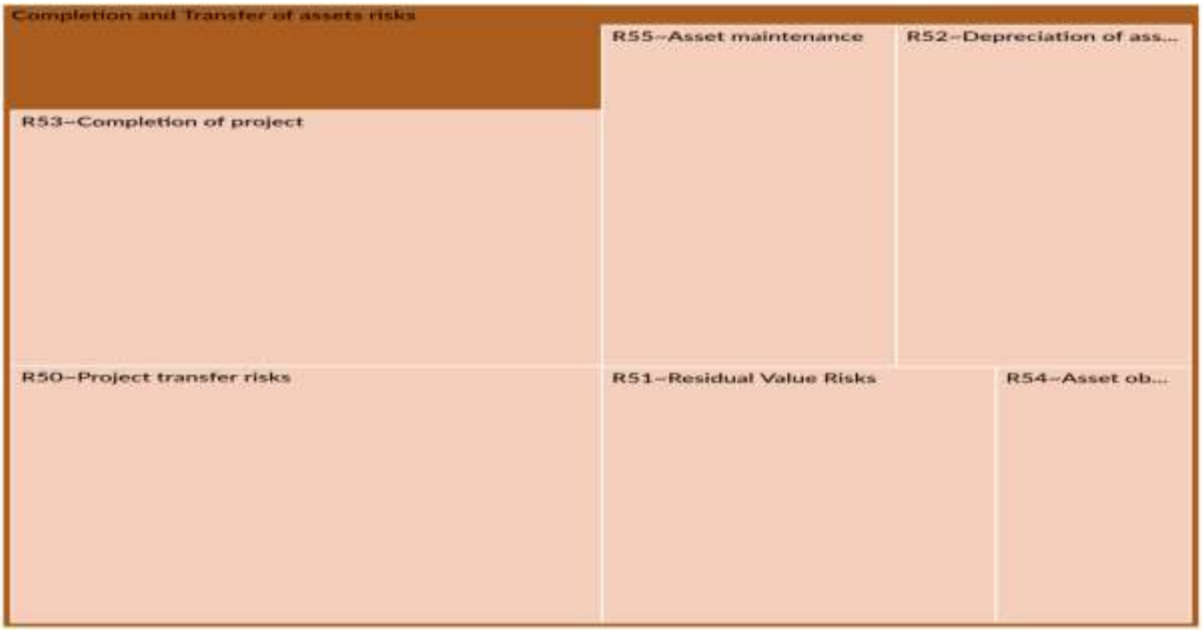

Figure 25 NVivo Hierarchy Chart for Completion & Transfer of Assets Risk for all three types of PPP Contracts category

5. Conclusion:

PPP infrastructure projects are essential collaborations between the government and private businesses. Making these projects successful means assessment of the possible risks that can happen at every stage, from planning to finish of the project. Therefore, the objectives of the study are i) Qualitative preference/prioritization of the risks of PPP infrastructure projects and their subsequent allocation in various execution modes of PPP infrastructure projects through NVivo software analysis from the public perspective and ii) Quantitative multistage risk prioritization of PPP infrastructure projects through AHP analysis from the general/stakeholders' perspective. Sorting the risks into these stages/phases and categorizing help to understand the challenges of each category and PPP project phase individually to understand better the priority/preference of risks and subsequently, its preferred allocation to devise plans and deal with them more effectively.

A comprehensive risk assessment and prioritization of the data gathered from the respondents / PPP experts by using AHP shows the ranking of these risks in various stages/phases of the PPP infrastructure projects' life cycle, as shown in Appendix A. The seven (07) life cycle stages of the PPP infrastructure projects were prioritized using AHP analysis. It is evident that S4: Construction and Execution Risks phase holds the highest priority vector followed by S1:Planning, design, and feasibility risks, S3:Legal and Procurement risks, S2:Financial Risks, S6:General & Project Environmental Risks, S5:Operation and Maintenance Risks and S7:Project Completion and Asset Transfer risks. Furthermore, the top ranked risks in each of these phases are R31:Scope creep, R4:Improper preliminary survey, R20:Legally weak partnership or strategic alliance, R11:Revenue shortfall, R46:Lack of R&D in the PPP regime, R37:Operation and maintenance and R53:Completion of the project respectively from the general/stakeholders perspective.

However, the results of NVivo hierarchy charts for preference and allocation of risks to the concerned stakeholder in the relevant PPP execution mode are determined and shown in the risk allocation matrix (Appendix A). It shows that the overall risk rankings includes R8:Microeconomic variables, R42:Corruption, R50:Project transfer risks, R43:Political instability, R37:Operations and Maintenance risks, R22:Tenant risks, R40:The uncertainty in rent prices, R14:Ownership of assets, R54:Assets obsolesce, R7:Poor cost estimation, R1:Improper design and technical study, R9:Availability of finance, R23:Lack of flexibility in contracts, R31:Scop Creep,R38:Demand and revenue shortfall, R15:Change in law, R11:Revenue shortfall and R20:Legally week partnership or strategic alliance are key risks from the public perspective. The following Fig. 26 & 27 show these risks ranking graphically.

Similarly, the preference of risks varies for each PPP execution mode and life cycle phase. For example, in the S1:Planning, design, and feasibility risks phase, the hierarchy charts show that R7:Poor cost estimation is the most preferred risk in all three (03) categories of PPP modalities, i.e. DBFOT/BOT type of PPP Contracts, Lease/Afferemage/BLT type of PPP Contracts and Ownership/BOOT types of PPP Contracts. Likewise, in S2:Financial Risks, R8:Microeconomic Variables is the most preferred risk for all three PPP categories' NVivo hierarchy charts. In S6:General and Project Environment Risks, R42:Corruption is the most preferred risk for all three PPP categories' NVivo hierarchy charts. However, in S3:Legal and Procurement Risks, S4:Construction & Execution Risks, and S5:Operation and Maintenance Risks, the risk preference varies for each PPP execution mode, as detailed in Appendix A.

Giving each risk a rank helps project managers and others decide which problems to solve first. Some problems need quick attention and solutions. Looking after these big problems from the start can make the project go better and get more benefits. Taking care of the project over time is important too. Thinking about how the project will keep running and how it affects the environment matters a lot. Looking ahead, the researchers need to keep finding better ways to figure out these problems. Using new technologies and studying how other projects succeeded can help us deal with risks in the best way. The large number of PPP execution modes leads to fewer experts available worldwide. Therefore, the percentage of shared risk allocation may be another objective of future research for a deep understanding of risk allocation. The following Fig. 26 & 27 show the overall comparison of risk ranking/preference using AHP and NVivo for respondents' general/stakeholders' perception and public perception, respectively, about each risk in the PPP infrastructure project.

Future researchers can prioritize the identified risks for their subsequent equitable allocation from the perspective of all stakeholders for all three categories to manage the risks properly. Due to a large number of PPP execution modalities opted for the PPP infrastructure projects, it was difficult to find experts worldwide with hands-on experience in each modality, which was the limitation of the study. Therefore, these execution modalities are categorized into three (03) different categories that somehow reduce the impacts of limitation on the results of the current study.

Looking ahead, the future researchers can explore and identify the extent of risk sharing among the various stakeholders to figure out this research gap. Using new technologies and studying how other projects succeeded can help us deal with risks in the best way. A large number of PPP execution modes lead to fewer experts available worldwide. Therefore, the percentage share of risk allocation may be another objective of future research for an in-depth understanding of risk allocation.

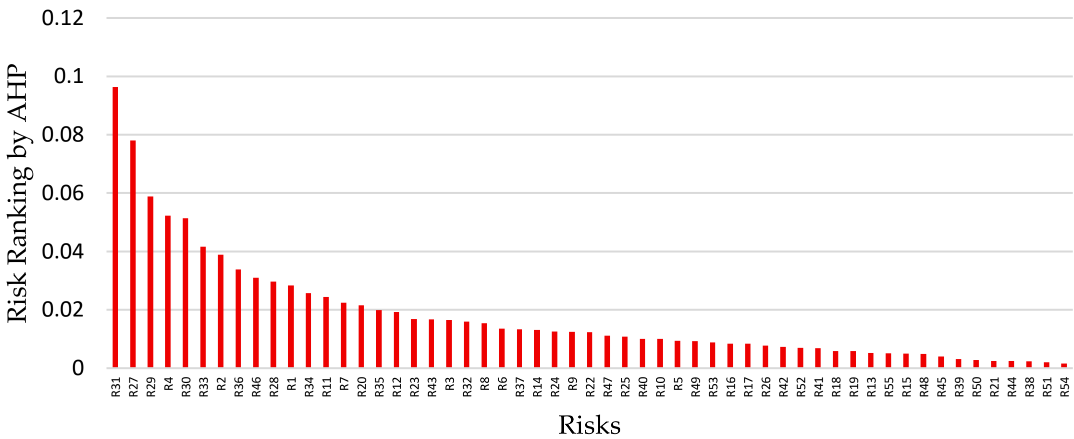

Figure. 26 Risk Prioritization in AHP Analysis, a general perspective

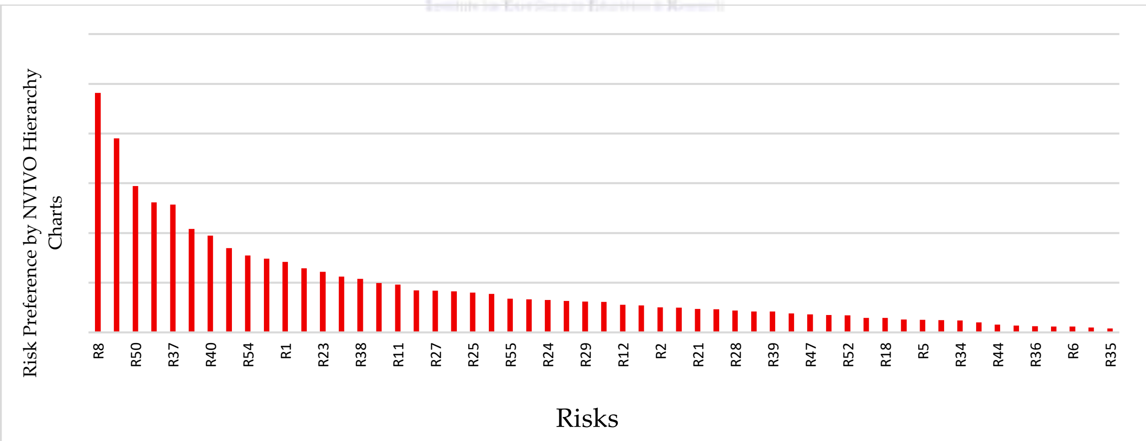

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Figure. 27 Risk Prioritization in NVivo Analysis, a public perspective

Appendix-A: AHP & NVivo Analyses for Stage-wise / Overall Risk Prioritization and Allocation for Various Categories of PPP Projects

Results	AHP analysis: PPP project phases & their subsequent risks AHP analysis priority based on their weightage							Overall ranking (AHP)-a general perspective		NVivo analysis: PPP projects execution modes and their priority based on NVivo analysis and their subsequent allocation of risk sharing preference by experts						Overall ranking (NVivo)-a public perspective
Execution Stages / Types	Planning Design and Feasibility Risks	Financial Risks	Legal and Procurement Risks	Construction & Execution Risks	Operation and Maintenance Risks	General and Project Environment Risks	Completion and Transfer of Assets Risks			DBFOT/BOT type of PPP Contracts		Lease/Afferemage/BLT type of PPP Contracts		Ownership/BOOT types of PPP Contracts		
Criteria Weightage	0.181	0.087	0.131	0.451	0.036	0.087	0.027			Stagewise Preference	Preferred Allocation	Stagewise Preference	Preferred Allocation	Stagewise Preference	Preferred Allocation	
S1: Planning Design and Feasibility Risks/ AHP analysis										S1: Planning Design and Feasibility Risks/NVivo analysis						
R1	0.157							0.028	11	2	Shared	2	Shared	2	Shared	11
R2	0.214							0.039	7	4	Govt.	4	Govt.	4	Shared	31
R3	0.091							0.017	20	3	Govt.	3	Govt.	3	Govt.	30
R4	0.288							0.052	4	7	Shared	7	Shared	7	Shared	44
R5	0.052							0.009	33	5	Shared	5	Shared	5	Shared	45
R6	0.075							0.014	23	6	Shared	6	Shared	6	Shared	53
R7	0.123							0.022	14	1	Shared	1	Shared	1	Shared	10
S2: Financial Risks/ AHP analysis										S2: Financial Risks/NVivo analysis						
R8		0.178						0.015	22	1	Shared	1	Shared	1	Shared	1
R9		0.144						0.012	27	2	Govt.	2	Govt.	2	Govt.	12
R10		0.115						0.010	32	5	Govt.	5	Govt.	5	Govt.	32
R11		0.281						0.024	13	3	Shared	3	Shared	3	Shared	17
R12		0.222						0.019	17	4	Shared	4	Shared	4	Shared	29
R13		0.060						0.005	44	6	Shared	6	Shared	6	Shared	54
S3: Legal and Procurement Risks/ AHP analysis										S3: Legal and Procurement Risks/NVivo analysis						
R14			0.100					0.013	25					1	Shared	8
R15			0.038					0.005	46	2	Govt.	4	Govt.	3	Govt.	16
R16			0.064					0.008	36	8	Shared	10	Shared	9	Shared	52
R17			0.064					0.008	36	7	Shared	9	Shared	8	Shared	46
R18			0.045					0.006	42	6	Shared	8	Shared	7	Shared	43
R19			0.045					0.006	42	4	Shared					28
R20			0.164					0.022	15	3	Shared	6	Shared	5	Shared	18
R21			0.019					0.002	51	5	Govt.	7	Govt.	6	Govt.	33
R22			0.094					0.012	28			1	Shared			6
R23			0.129					0.017	18	1	Shared	5	Shared	4	Shared	13
R24			0.096					0.013	26			2	Shared			25
R25			0.082					0.011	30			3	Shared			21
R26			0.059					0.008	38					2	Shared	22
S4: Construction & Execution Risks/ AHP analysis										S4: Construction & Execution Risks/NVivo analysis						
R27				0.173				0.078	2	2	Private	2	Private	2	Private	19
R28				0.066				0.030	10	5	Private	4	Private	4	Private	35
R29				0.130				0.059	3	3	Govt.	3	Govt.	3	Govt.	27
R30				0.114				0.051	5	4	Govt.					34
R31				0.213				0.096	1	1	Shared	1	Shared	1	Shared	14
R32				0.035				0.016	21	6	Private	5	Private	5	Private	36
R33				0.092				0.042	6	7	Shared	6	Shared	6	Shared	42
R34				0.057				0.026	12	8	Private	7	Private	7	Private	47
R35				0.044				0.020	16	10	Shared	8	Shared	8	Shared	55
R36				0.075				0.034	8	9	Shared	9	Shared	9	Shared	51
S5: Operation and Maintenance Risks/ AHP analysis										S5: Operation and Maintenance Risks/NVivo analysis						
R37					0.372			0.013	24	1	Private	1	Shared	1	Private	5
R38					0.067			0.002	53	2	Shared	3	Shared	2	Private	15
R39					0.089			0.003	49	4	Private	5	Private	4	Private	37
R40					0.282			0.010	31			2	Shared			7
R41					0.191			0.007	41	3	Private	4	Shared	3	Private	26
S6: General and Project Environment Risks/ AHP analysis										S6: General and Project Environment Risks/NVivo analysis						
R42						0.084		0.007	39	1	Govt.	1	Govt.	1	Govt.	2
R43						0.193		0.017	19	2	Govt.	2	Govt.	2	Govt.	4
R44						0.028		0.002	52	7	Govt.	7	Govt.	7	Govt.	49
R45						0.046		0.004	48	6	Shared	6	Shared	6	Shared	48
R46						0.358		0.031	9	3	Shared	3	Shared	3	Shared	38
R47						0.129		0.011	29	4	Shared	4	Shared	4	Shared	39
R48						0.056		0.005	47	8	Shared	8	Shared	8	Shared	50
R49						0.107		0.009	34	5	Shared	5	Shared	5	Shared	40
S7: Completion and Transfer of Assets Risks/AHP analysis										S7: Completion and Transfer of Assets Risks/NVivo analysis						
R50							0.101	0.003	50	1	Shared	1	Shared	1	Shared	3
R51							0.073	0.002	54					4	Private	24
R52							0.257	0.007	40					5	Shared	41
R53							0.324	0.009	35	2	Private	2	Shared	2	Private	20
R54							0.057	0.002	55					6	Shared	9
R55							0.188	0.005	45					3	Private	23

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Conflict of interest:

All the authors hereby certify that they have no affiliation with any of the organizations, firms or entity for any financial or non-financial benefit for this research study or material discussed in the study.

Ethical Approval:

The manuscript complies with the ethical standard and has never been submitted anywhere else for publication.

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